

GETTING THE MOST

for Your Asset Management Money with Lifecycle Costing



BY SHAYNE C. KAVANAGH

The acquisition cost of an asset is just a portion of the total cost of owning it. Ongoing maintenance significantly adds to that cost, and for a long-lived asset, that cost can be much greater than the initial design, construction, and installation cost. Moreover, failure to keep up with regular asset maintenance can result in premature deterioration and an increased risk of failure, leading to even greater maintenance and rehabilitation costs. Lifecycle cost analysis considers the entire cost of owning the asset, over its useful life. One of the primary benefits of lifecycle costing for capital assets is that during initial asset acquisition, lifecycle cost analysis shows which asset is the most cost-effective over the long term, not just which is the cheapest to acquire. In addition, after the asset has been acquired, lifecycle cost analysis can be used to budget and plan for the most cost-effective maintenance strategies.

Pavement was one of the first asset classes that governments applied lifecycle cost analysis to.¹ This is because pavement is a relatively simple asset to analyze and because of the large cost of paving in government budgets. This article will provide an introduction to lifecycle cost analysis, using pavement and the City/County of San Francisco, California, as an illustration.

In 2010, the city found that the cost of underfunded preventative maintenance on its streets had resulted in the streets deteriorating to the point where almost half of them would require costly reconstruction. In fact, the city found that, without preventative maintenance, a San Francisco street would cost four times more over the course of 70 years than if it had been maintained regularly.² The city had a ten-year capital improvement plan that emphasized the need to find a financially sustainable way to keep the streets in acceptable condition.³ To do so, the city turned to lifecycle cost analysis.

BUILDING LIFECYCLE COST ANALYSIS

San Francisco first needed a basic model for how streets deteriorate and how performance and remediation costs change at different points in the asset's lifecycle. The city built its model around the pavement condition index, or PCI, which is an industry-standard measure of street quality. Under

PCI, a street is rated 0 to 100, where 100 is the best condition. A measure of asset condition is essential for lifecycle cost analysis because an asset might require more or less costly maintenance treatments at different conditions. For example, the city found that the average cost to maintain a street block is between \$15,000 and \$37,000⁴ when the PCI of that street is between 79 and 60. However, when the PCI dips below 60, the same routine maintenance is no longer sufficient to make a meaningful repair. Instead, when the PCI is between 59 and 50, the road must be resurfaced, at a cost of \$144,000 per block. Below 50 PCI, and the road must be reconstructed. This can be quite costly. Reconstructing a road between 0 and 24 PCI costs approximately \$510,000. Reconstructing a road between 49 and 25 PCI is less costly, but still considerable at \$167,000. Obviously, if the city allowed its streets to deteriorate too much, the long-term cost would be enormous.

(The city tracks PCI through periodic physical evaluations.)

The city's model of street deterioration needs to be informed by an understanding of the local conditions that contribute to street deterioration: primarily, traffic patterns and weather.

For traffic, the city takes into account traffic flows and utilization. The city considers three types of roads, using categories that are common to urban planning: residential (least busy), collectors, and arterials (busiest). The city also accounts for what kind of vehicles (e.g., trucks versus automobiles) use a road as a proxy for determining weight loads, which have a significant impact how quickly a street deteriorates.

With respect to weather, San Francisco's streets are exposed to saltwater and fog, especially near the ocean coastline. Humidity accelerates the deterioration of streets. Fortunately for the city, San Francisco's streets do not experience exposure to ice, snow, or extreme hot and cold temperatures — all of which have a significant negative impact on pavement.

All these variables help the city identify a deterioration curve, which is a model for how quickly a given street will deteriorate over time. Deterioration curves are necessary for lifecycle cost analysis of any type of asset because the curve reveals the most cost-effective point at which to perform a

Pavement was one of the first asset classes that governments applied lifecycle cost analysis to. This is because pavement is a relatively simple asset to analyze and because of the large cost of paving in government budgets.

maintenance project. To develop a curve, you need a robust set of historical condition, age, and failure data, which suggest how quickly the asset deteriorates. They also allow a government to differentiate the performance of different types of assets. For example, they might show that an asphalt street will deteriorate faster than a concrete one. The factors that influence deterioration, other than age, also need to be factored in. Traffic volume, weight, and environmental factors are most important for roads. Other assets might be affected by factors including operating hours, peak loads, and operating pressure. In some cases, the materials involved, technologies/design standards, and even specific equipment manufacturer and models might have a significant impact on the size and shape of the deterioration curve. We'll see San Francisco's curve, combined with cost data, in the next section of this article.

The final piece of the foundation for lifecycle cost analysis is historical costs, which are used to model expected future costs. The city takes historical costs from completed street maintenance projects. City staff also speak with local contractors and other people knowledgeable of the construction market to get a sense of the direction costs are headed. For example, petroleum is a key ingredient in street repair, so if the price of oil is rising, street repair costs will, too.

USING LIFECYCLE COSTING TO GUIDE DECISION MAKING

Making decisions with lifecycle cost analysis requires fashioning the foundational elements described above into a decision framework. San Francisco combines its deterioration curve with cost data to create one of their primary decisions tools: an S-curve. An S-curve is a common statistical method, so called because of the S-like shape of the curve. It is flatter at the beginning and end and steeper in the middle (see Exhibit 1). S-curves are often used in engineering and business applications. For example, a new product may not sell briskly at first because it needs to find its market. This would be represented by the lower left-hand portion of the line in Exhibit 1. At some point, sales increase more rapidly (the

In 2010, the City/County of San Francisco found that the cost of underfunded preventative maintenance on its streets had resulted in the streets deteriorating to the point where almost half of them would require costly reconstruction.

middle of the line). Eventually, sales level off as the market becomes saturated (the upper right-hand portion of the line). An S-curve could be oriented like a standard S, as in Exhibit 1, or a backward S, like we will soon see.

San Francisco's S-curve (shown in Exhibit 2) is a little more complex than that shown in Exhibit 1, but the basic concept is the same. We see that at the top of the curve, the rate of deterioration is slower and, thus, the line is flatter. Then, the rate of deterioration increases and the line gets steeper. Finally, as we approach a PCI of zero, the line flattens out again. Exhibit 2

shows that quality drops much more rapidly after the road deteriorates beyond a certain point (60 PCI). It also shows the cost to restore the road to 100 PCI is at least five times greater when the PCI drops to 20 versus when it drops to 60. The shape of the S-curve varies for different kinds of streets. A street with more traffic, which is used by heavier vehicles, or a street that is closer to the ocean and thus exposed to more fog and saltwater, deteriorates more rapidly than a street that is not exposed to these conditions, all else being equal.

Exhibit 3 links multiple S-curves together for more sophisticated lifecycle cost analysis. In Exhibit 3, the yellow line is two S-curves. It shows a hypothetical case where the city conducts no maintenance and simply lets a road deteriorate to the point of complete collapse and then rebuilds it, twice over a 70-year

Exhibit 1: An S-Curve Archetype

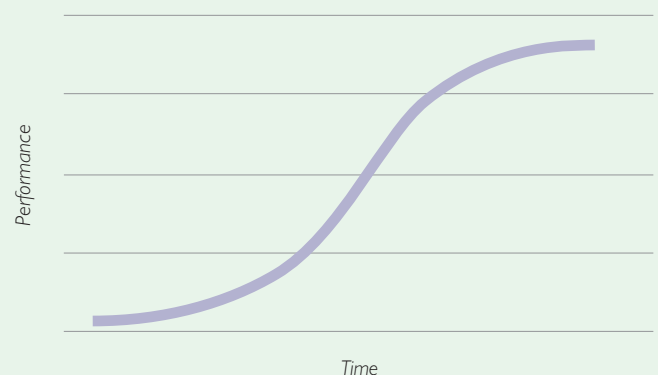
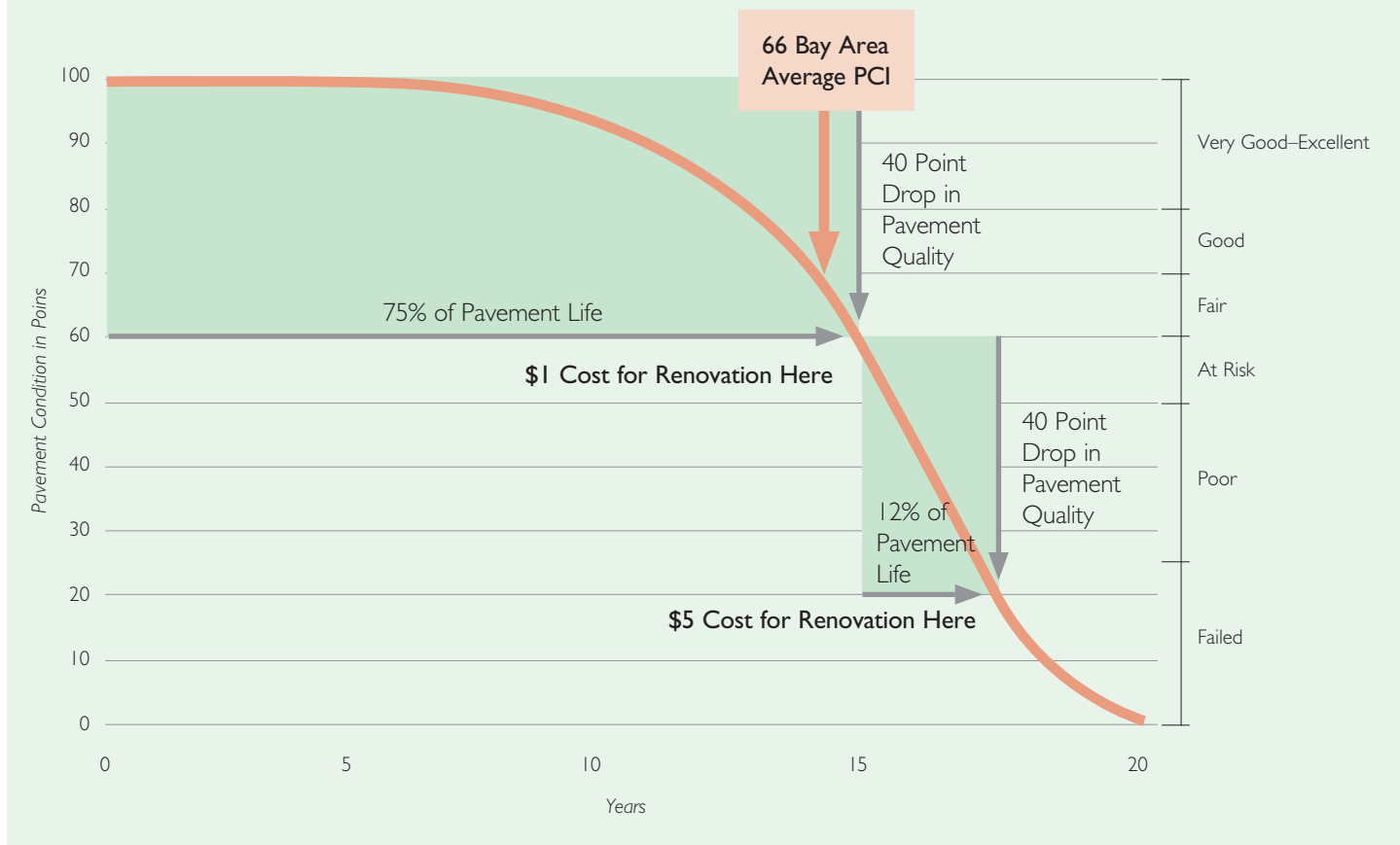


Exhibit 2: Pavement Lifecycle for a Street in San Francisco



period. The blue lines show several smaller S-curves that represent a more proactive maintenance strategy. Here, a road deteriorates until it reaches a PCI in the mid-80s. Then a minor preservation project is sufficient to restore some of the road's condition. This repeats when the road reaches a PCI in the mid-70s. Once the road reaches a PCI of 50, a paving project restores the road to a PCI of 100. Hence, the road never reaches the point (PCI of 49 or below) where reconstruction is needed.

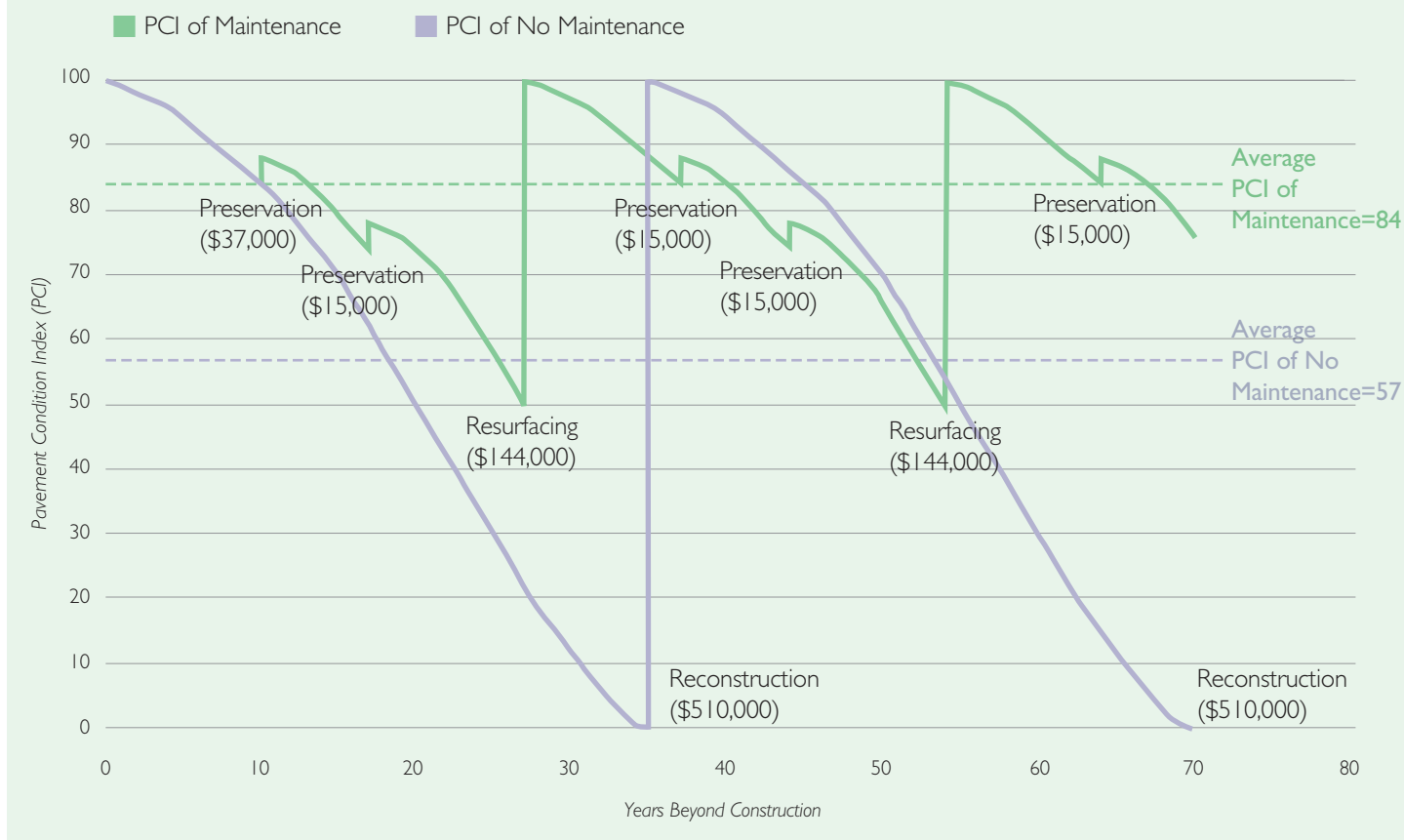
The S-curve shows that the total cost of street maintenance over 70 years is less with the strategy described by the blue line. The total cost of the

San Francisco first needed a basic model for how streets deteriorate and how performance and remediation costs change at different points in the asset's lifecycle. The city built its model around the pavement condition index, or PCI, which is an industry-standard measure of street quality.

projects contemplated by the blue line is \$385,000, while the total cost of those contemplated by the yellow line is more than \$1 million. Of course, the residents and visitors to San Francisco also enjoy substantially better street quality with the strategy shown by the blue line, which delivers an average PCI of 84 over the 70 years. The average PCI for the "no maintenance" scenario is of 57.

This same model could be used to consider other approaches as well. For example, if the city only did paving projects and did no interim preservation projects, it would need to do four paving projects during the 70-year

Exhibit 3: San Francisco's Pavement S-Curve for Lifecycle Costing over a 70-Year Period



period to stay above 50 PCI. This would come to \$576,000. (This scenario is not depicted in Exhibit 3.)

The S-curve for lifecycle costing has helped the city find the most cost-effective approach to maintaining its streets. First, it clearly shows what happens if the city fails to maintain its streets: The PCI will fall below 50, thereby necessitating costly reconstruction. This highlights the need to direct adequate fund street maintenance in order to prevent this from happening. In fact, City Council members now explicitly ask how potential cuts in funding would impact PCI. Second, discussions on which area of the city should receive street maintenance dollars can be grounded in objective data. There is a compelling case for directing funding to streets where PCIs are in danger of falling

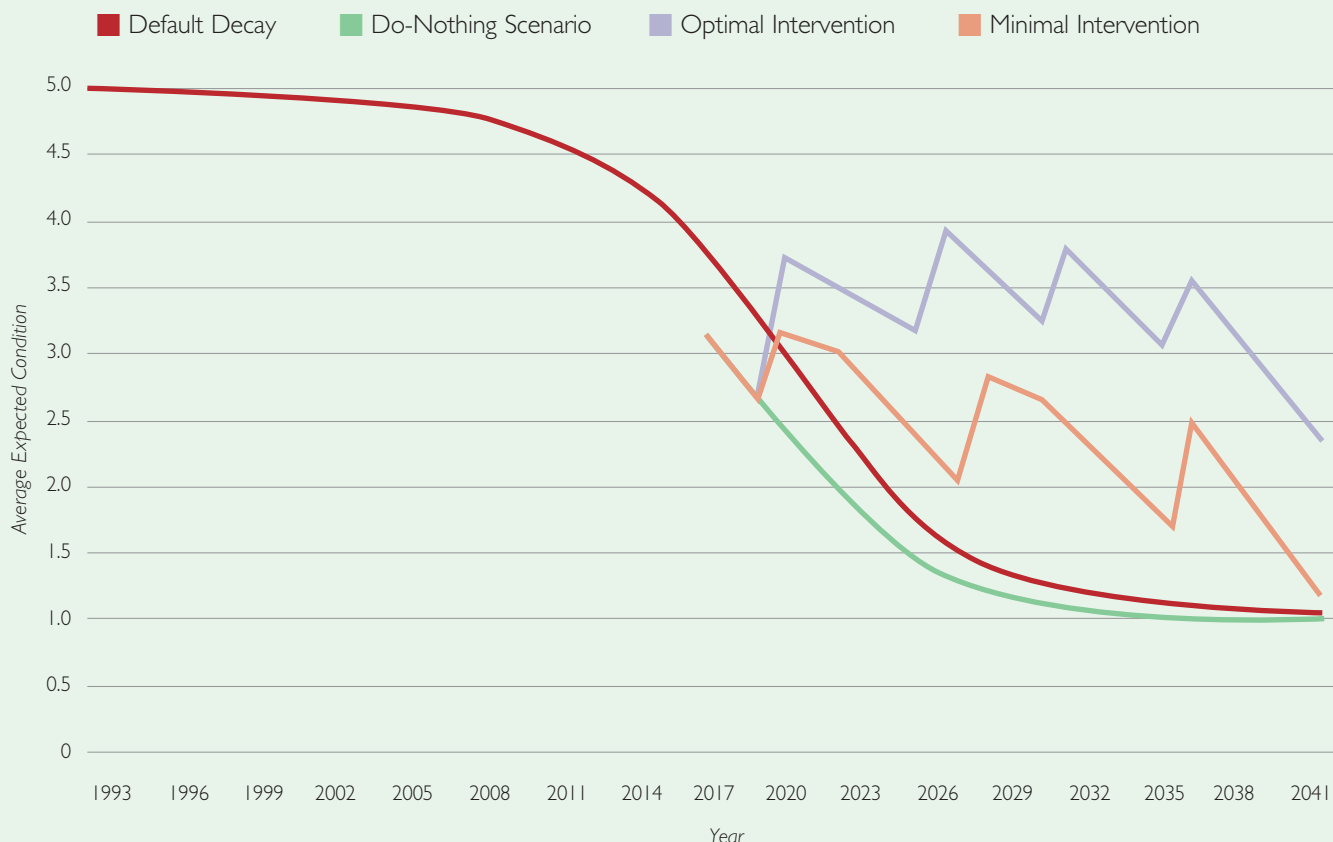
below 50 or where it is otherwise cost-effective to perform a maintenance project. This brings more equity in spending because discussion is focused on maintaining acceptable street quality in all neighborhoods. Finally, the lifecycle cost analysis spurred a discussion about new funding sources for

street maintenance so the city could bring its worst streets above 50 PCI and eventually get all streets on a cost-effective maintenance program.

To develop a curve, you need a robust set of historical condition, age, and failure data, which suggest how quickly the asset deteriorates. They also allow a government to differentiate the performance of different types of assets.

S-curves can be used for asset classes other than streets. Exhibit 4 shows a set of curves used by an airport to help make a rehabilitate-versus-replace decision for 25-year old parking garages. The airport compared the garages' current condition to industry-standard deterioration curves. This allowed the airport to examine the cost/benefit of multiple investment scenarios.

Exhibit 4: S-Curves for a Parking Structure



These scenarios ranged from “do nothing,” to complete replacement, to an optimal maintenance intervention for the existing garages. The lifecycle cost analysis was used to justify investments over the remaining 25 to 30 years of life of the garages. Continued investments under the “minimal” and “optimal” intervention scenarios were determined to be four to five times more cost-effective than building a new structure.

LESSONS LEARNED

San Francisco’s experience with lifecycle costing holds a number of lessons for other local governments that would like to improve their financial decision making when it comes to asset acquisition and maintenance.

Get Started with Lifecycle Cost Analysis on Pavement or Another

Easy-to-Model Asset. Pavement is a relatively simple asset, where the condition of the asset is easy to measure, historical maintenance costs are widely available, and the conditions that contribute to deterioration of the asset are well known. Further, street maintenance is often a large budget item for local governments, so the potential financial benefits of better decision-making is substantial. But

pavement is not necessarily the only asset that has these characteristics. Other assets might include pipelines and mechanical equipment (e.g., pumps or motors).

Find a Compelling Question to Answer with Lifecycle Costing Analysis. In San Francisco, street condition had become a high-profile issue, and people wanted to know the best way to keep the streets in good repair. Lifecycle costing answered that ques-

The city’s model of street deterioration needs to be informed by an understanding of the local conditions that contribute to street deterioration: primarily, traffic patterns and weather.

tion. If a compelling question exists for an asset class other than pavement, that asset class might be a good starting point for lifecycle costing.

Use a Measure of Asset Condition that Speaks to the Public's Experience. Lifecycle cost is an abstract concept, but the quality of the ride on a road is concrete. PCI is a direct indicator of the quality of the experience the public will have when using roads. This makes discussion of road maintenance more meaningful for elected officials and others, and thus, makes lifecycle cost analysis more compelling.

Develop an Easily Understood Decision Framework. San Francisco's S-curve shows how pavement quality relates to potential investment decisions at all points in the asset lifecycle. The S-curve helps everyone involved in the decision process understand the implications of lifecycle costing analysis. ■

Notes

1. "Maximizing the Value of Investments Using Life Cycle Cost Analysis," American Society of Civil Engineers and Eno Center for Transportation, 2014.

Governments consider a number of variables in identifying a deterioration curve, which is a model for how quickly a given street will deteriorate over time.

2. "Between a Pothole and a Hard Place: Funding Options for San Francisco's Street Resurfacing Program," City and County of San Francisco, June 8, 2010.
3. Available at onesanfrancisco.org/the-plan/overview.
4. The first instance of a Pavement Condition Index preservation project on a new street entails certain costs that do not have to be incurred again in subsequent preservation projects.

SHAYNE KAVANAGH is the senior manager of research at GFOA. He can be reached at skavanagh@gfoa.org. Kavanagh would like to thank the following people for their assistance with this article: **PAUL BARRADAS**, project manager, Public Works Street Resurfacing program; **RAMON KONG**, Street Resurfacing Program manager, Public Works Department; and **BRIAN STRONG**, chief resilience officer and director, Office of Resilience and Capital Planning, all for the City and County of San Francisco; David C. Sklar, Water and Utilities Asset Management leader; and Becky Moylan, senior manager, Public Affairs and Media Relations, American Society of Civil Engineers.

